Conservation of Tissue and Function in Pulmonary Resection

The Technique of the Anatomical Separation of Segments

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SUMMARY

Total ablation of an entire limb to remove a small benign granuloma or tumor is unthinkable. Yet when an entire pulmonary lobe is removed for a similar lesion the sacrifice of normal tissue and function is taken for granted. Operations upon the lung commenced with pneumonectomy, were made more selective by lobectomy, and now can be confined to resection of single pulmonary segments when the diseased area is no more extensive, or to single segments in several lobes if necessary.

Technically the pulmonary segment is the unit of pulmonary resection. The separation of one from another, or even a half of one from the other half, can be accomplished with anatomical accuracy. More widespread use of this operation will provide surgical aid to many bronchiectatic patients who otherwise are afflicted with disease too widespread for cure. It will conserve healthy lung tissue in benign conditions where removal of the diseased area is necessary.

The technical steps of pulmonary segmental resection are outlined and illustrated.

WHY do general practitioners and internists not refer patients with a single round or wedge-shaped mass in the lung for operation? Why do thoracic surgeons remove so much good lung in excising small benign pulmonary lesions? These questions are connected.

When a physician observes a patient with a benign tumor of the hand or arm, or a localized granuloma, or a crippling scar he does not watch the lesion by physical examination and repeated x-ray study for many months. He arranges for surgical removal. If he finds a mass in a woman's breast he doesn't, nowadays, pursue a course of watchful waiting or dismiss the finding as of academic interest only. He insists on immediate surgical removal for a positive early diagnosis and an optimal opportunity for cure if malignant change is present. A localized pulmonary mass, round or wedge-shaped on x-ray examination, cannot be palpated, trans-illuminated, tested for tenderness and so on as can a mass in the breast. With so little information to go on, why should a physician procrastinate and not have biopsy performed early? The principal deterrent is, probably, his consideration of both the risk of pulmonary resection and the extent of resection practised even when the lesion is benign. The risk, once great, is no longer significant in comparison with the potential danger of the lesion itself. The extent of resection, at first total pneumonectomy and later lobectomy, can now be limited to the pulmonary unit or units involved,[5, 7, 8, 9, 10] except when malignant change is present. When physicians recognize these facts they will react to a pulmonary mass as to a tumor of the breast.

Thoracic surgeons should conserve the maximum of normally functioning pulmonary tissue. That not all of them do is owing to a paradox of pulmonary resection. Here, unlike excisional operations upon the brain, limbs, intestine and so on, but perhaps akin to renal operations, it is technically easier to remove an entire lung than a lobe, or a lobe than a segment. Thus it used to be that if surgical removal was to be done, total pneumonectomy was necessary. When lobectomy was mastered, that was the most conservative and function-preserving operation that could be offered. Thoracic surgeons are now in the process of changing to the segment as the unit of pulmonary resection.[2, 3, 5, 6, 7, 8, 9, 10]

Pulmonary segmental resection is valuable not alone for biopsy of a localized mass or for removal of a localized benign process; indeed, perhaps the greatest usefulness of the procedure is in dealing with bronchiectasis.[2, 6, 7, 8, 9] This disease, commonly misdiagnosed as chronic bronchitis, or asthma, is a disease of lung segments. Usually it affects *some* segments of *several* lobes. The only cure for the condition is surgical removal of the diseased areas, but unless a more selective operation than lobectomy is employed, only a small proportion of persons who have the disease can be so treated, for in most cases too many lobes contain involved segments. If only the diseased segments of lobes are removed and the normal tissue of each affected lobe is preserved it is possible to completely remove the bronchiectatic segments in most cases. (See Figure 1.) In typical severe cases, the lingula, the middle lobe, and both lower lobes are involved, but the superior segments of the lower lobes, comprising by volume about three-sevenths of the two lobes, are normal. Each such superior segment is roughly equivalent in size to a middle lobe or to both segments of a lingula. Preservation of these superior segments, which is standard in seg-

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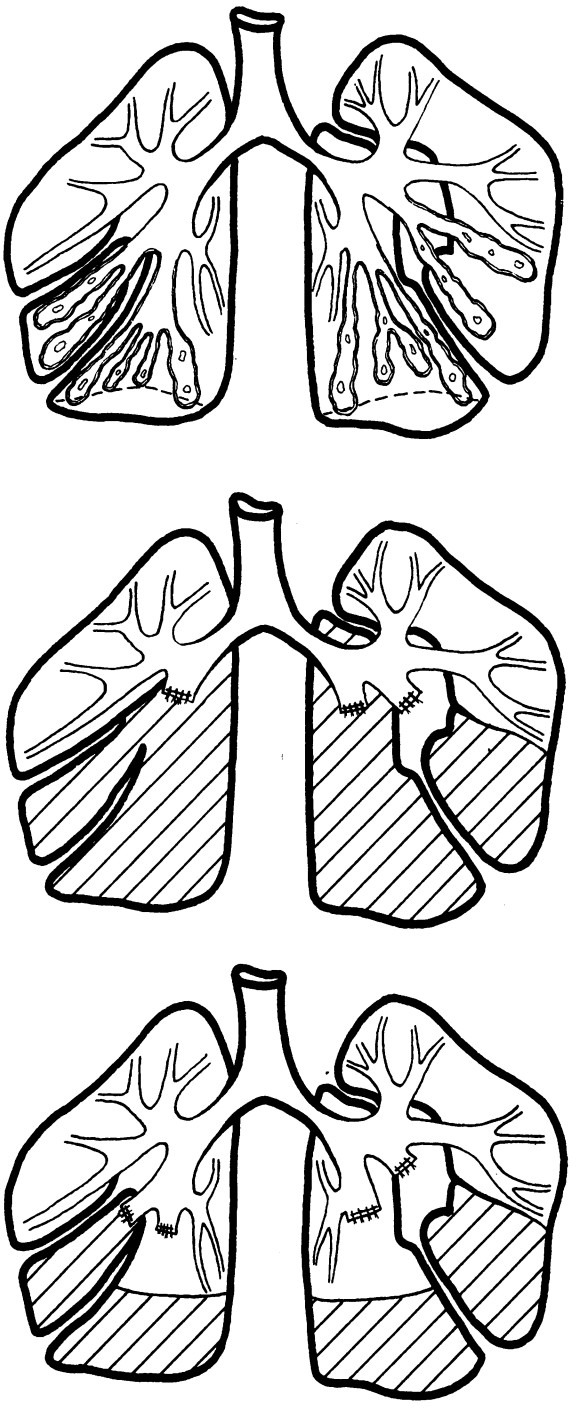

Figure 1.—*Upper*—The common distribution in bilateral bronchiectasis. Note that both lower lobes are involved but the superior segment of each, totaling about three-sevenths by volume, is not involved. The middle lobe and lingula segments are involved. *Middle*—Excision of the involved segments by lobectomy and lingulectomy results in extensive loss of lung tissue, including the normal superior segments of both lower lobes which together aggregate as much tissue as the middle lobe and lingula combined. This excision leaves only six pulmonary segments (equivalent of two right upper lobes) for function. *Lower*—Excision of the diseased segments only preserves the superior segments of the lower lobes and thus leaves the equivalent of two right upper lobes, a middle lobe and a lingula for function.

mental excision,[7, 8, 9] permits removal of both the middle lobe and the lingula with a total tissue loss equivalent to two lower lobes—yet diseased segments have been removed from four lobes. For bronchiectasis of minimal extent but with definite symptoms present, it is no longer necessary to remove half of a lung when only one, or two, segments of one lobe are involved. (See Figure 2.) The preservation of all normal lung tissue is of great value in the patients, most of them young, both for immediate maximum function and for protection from pulmonary insufficiency in case of future pneumonia, emphysema, asthma, bronchogenic carcinoma or cardiac disease.

A field of promise for segmental resection is pulmonary tuberculosis. Here there is often a localized problem, such as a thick-walled cavity or thin-walled tension cavity, which defies more routine therapeutic measures. Often there is sufficient disease of non-cavitary or minimal cavitary nature in the same or opposite lung that thoracoplasty or lobectomy is impracticable. Removal of the one or two segments containing the major lesion will sometimes preserve enough function so that other measures, not otherwise possible, can be utilized to control the remaining disease. In time, segmental resection of localized cavities may become the treatment of choice, since the two methods now commonly used—collapse of a lobe or removal of a lobe—result in extensive loss of function. Such a development will be greatly forwarded by discovery of an antibiotic even more effective than is streptomycin.

ANATOMY

Both physiologically and technically the separation of one part of a lobe from the remainder is dependent upon anatomic factors.[1, 2, 3, 9] These are: (1) the fundamental unit of gross pulmonary structure, and (2) the peripheral nature of the venous drainage of such units.

The fundamental unit is considered to be a conical structure of pulmonary parenchyma which has a central bronchus and artery of supply and a network of veins, arranged peripherally and converging at the apex of the cone where the bronchus and artery enter.[1, 9] The actual size of this fundamental unit has not been determined (so far as is known to the author), but all bronchovascular segments contain at least two and many at least four. A quarter of a single segment is probably the smallest portion of lung that it is practical to remove for excision of a diseased process, and further divisions down the scale need concern us, surgically, no further. Whether or not the fundamental unit has a central vein is not known, but it is not unlikely.

Two or more fundamental units are always combined to form larger units. When they do so the peripheral veins at the points of contact mark the borderline between individual units; therefore they can be called inter-unitary veins. Theoretically, then, regardless of the size, any unit can be separated from its neighbor by locating the inter-

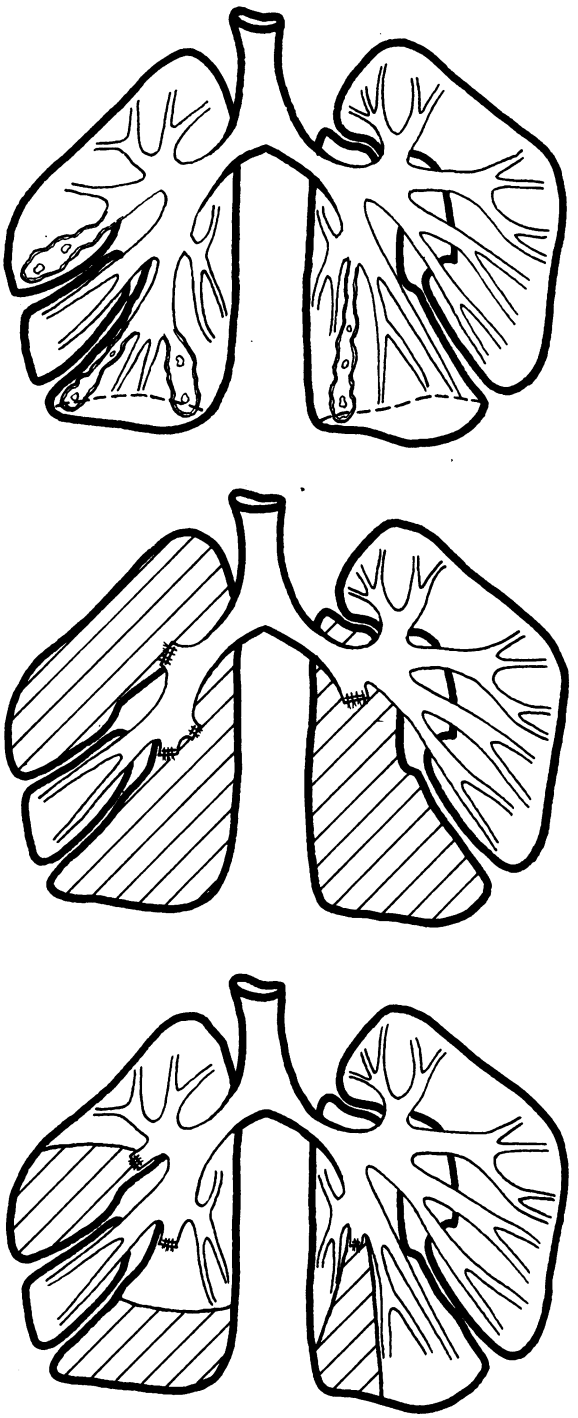

Figure 2. — Illustrating the extreme waste of normal functioning lung that can occur if lobectomy is used rather than segmental excision. Bronchiectasis is a disease of some segments in various lobes. *Upper*—Scattered bronchiectasis, involving four segments in three lobes. *Middle*—Excision of the diseased areas by lobectomy involves the removal of three entire lobes, leaving only a complete left upper lobe and a middle lobe for function. *Lower*—Excision of the diseased areas by segmental resection, preserving nearly all the normal lung. Note: It is quite feasible to remove only the two diseased basal segments of the right lower lobe, but here the remaining two might become rotated or displaced with resulting bronchial obstruction and disease so that often if two basal segments are diseased all are removed. In some circumstances the surgeon might elect to preserve all the normal segments.

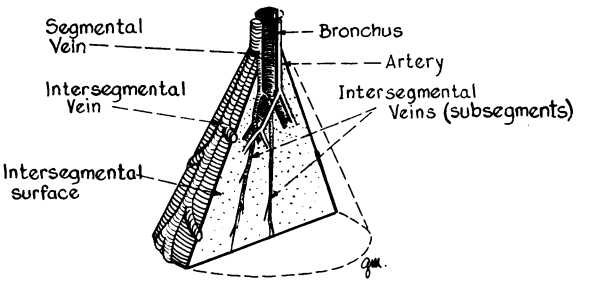

Figure 3. — A bronchovascular segment, in this case formed from four "units." The segmental bronchus and artery enter at the apex of the segmental cone. Their branches enter the apices of the component "units." The principal venous drainage is peripheral with several trunks converging at the apex. These trunks run in the plane between this and any adjacent segment and therefore are called intersegmental veins. They can be located at the segmental hilum and followed peripherally as guides to the cleavage plane between adjacent segments. A smaller vein can be seen adjoining the central bronchus and artery at the apex; it is called the segmental vein. If traced into the segment its branches can be seen to come from the junction surfaces of the component units. The branches are therefore inter-unitary veins. (Modified from Figure 2, Reference Number 9.)

unitary vein and following it and its branches in the plane of separation.

When two fundamental units are thus combined, there is formed a structure with (1) peripheral veins on the noncontact surfaces converging on the common hilum, (2) one or more veins running between the formative units at the plane of contact (inter-unitary veins), (3) a junction of the peripheral veins and the inter-unitary veins at the hilum to form a common trunk, (4) a bronchus of supply for each unit at the hilum combining to form a single bronchus, and (5) an artery of supply for each unit combining to form a single artery. Thus the combination unit has a central artery and bronchus and peripheral and inter-unitary veins.

When more than two units unite, the same principle is found. Two or more groups of fundamental units may combine to form segments or lobes of any size. A group of any size will have a single bronchus, an artery, and two types of veins—peripheral veins, marking the group off from adjacent groups, and central veins constituting one or more inter-unitary veins. The central vein will often be found with the group bronchus and artery.

The largest components of any lobe are the bronchovascular segments. These have been named and the bronchus of supply is of the third order, after the main stem bronchus and the lobar bronchus. This is the lobar subdivision which is generally referred to by the term "segment" (Figure 3). Like any smaller group of lung units, it has centrally a (segmental) bronchus, (segmental) artery, often a (segmental) vein and peripheral veins converging on the hilum. Some peripheral veins mark the plane of separation from a contiguous segment and are known as intersegmental veins; the remaining are covered by pleura and are called subpleural.

Vein Classification:

Central — a. — The segmental vein[9] originating from inter-unitary veins of smaller units or groups

(subsegments). It accompanies the central artery and bronchus.

Peripheral—a.—The intersegmental vein[1,9] which runs peripherally in the plane of junction with adjoining segments.

b.—The subpleural vein which runs peripherally on a free surface and is covered with pleura.

A subsegment is a smaller portion of a segment and may be of various orders of segmental division. All subsegments have the unitary structure described above.

SURGICAL SEPARATION

Surgical separation of a segment (or subsegment) consists essentially of division of the central structures (segmental bronchus, segmental artery and segmental vein, if present), any subpleural veins, and then the separation from contiguous segments (or subsegments) by locating the intersegmental vein (or veins) at the segmental hilum and following it and its branches along the plane of fusion, dividing the small venous tributaries as they are encountered. This having been accomplished to the pleural surface, the segmental resection has been completed. Occasionally circumstances will be found which will make preferable a variation in the order of the steps outlined.

In performing the procedure outlined in the preceding paragraphs, certain natural aids are employed. The diseased segment is usually apparent by inspection or palpation; occasionally bronchographic evidence only is of assistance. Since the segmental bronchus contains cartilage it can be palpated with ease and followed by touch into the segment until there is no doubt that it supplies the diseased segment. This having been carefully done the bronchus is dissected, clamped distally, sectioned near its origin, and the proximal stump sutured closed. The segmental artery accompanies the bronchus and is therefore exposed during the dissection of the bronchus. It is doubly ligated and divided when encountered. Any subpleural veins and/or segmental veins which are present are doubly ligated and divided as they become evident. The segment is then detached from the adjacent lung parenchyma by using the intersegmental vein as a guide to the plane of separation.

How is the intersegmental vein, of a given plane, recognized? The answer is: By anatomical details. Dissection must be at the hilum of the segment being removed; otherwise the incorrect bronchus, artery and veins will be found—structures belonging to segments or subsegments of a higher or lower order. Commencing with the correct bronchus will make evident the hilum of the diseased segment. At this hilum, as was pointed out in the anatomical discussion, there may be found one or more segmental veins, or subpleural veins, or intersegmental veins. Any vein discovered by gentle dissection at the segmental hilum should be followed distally for a short distance. If it follows the segmental bronchus and artery closely into the center of the segment, it is a segmental vein; if it does not, but runs subpleurally, it is a subpleural vein. If it does not follow either of those courses nor any other bronchus or artery, but passes into the parenchyma at the approximate junction of neighboring segments, it is the intersegmental vein.

The intersegmental vein is then followed peripherally between the segments. In most instances the intersegmental vein arises equally from adjacent segments and should be preserved by dissecting between the vein and the diseased segment. Following the vein is facilitated by flattening out the intersegmental plane by the use of mild positive intrabronchial pressure—the anesthetist does this—and applying lateral divergent pressure on the margins of the plane. Care must be taken not to put too much traction on the diseased segment, lest the veins be rendered bloodless and difficult to follow. Separation of the surfaces should be by gentle pressure with the fingertip or the blunt end of scissors. Small venous tributaries and any fibrous strands should be divided with scissors as encountered, since undue traction on them is transmitted to the adjacent healthy segment with resultant trauma and leakage of air.

After the segmental separation has been completed, the pleura is divided and the segment discarded. Usually there are a few small venous branches that must be ligated and several places that leak air. Small air leaks can be disregarded, but vigorous ones usually come from tears in small bronchi with cartilage in the walls. These may persist as fistulas unless ligated closed. Nothing further then remains to be done to the intersegmental surface, except that in tuberculosis it may be advisable to cover the exposed surface with free pleura.

The after-care of patients does not differ from that following lobectomy.

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